

IMMUNOLOGICAL METHODS FOR THE TREATMENT OF GASTROINTESTINAL CANCER

BACKGROUND OF THE INVENTION

The mature gastrin hormone occurs in two molecular forms which are named with respect to the number of amino acids in the peptide, i.e., tetratriacontagastrin (G34) and heptadecagastrin (G17). In gastrin producing cells, these gastrin hormones are posttranslationally processed from a common precursor molecule termed "preprogastrin", which contains a signal peptide. The signal peptide "pre" is removed in the endoplasmic reticulum of the cell, resulting in the "progastrin" peptide, which is in turn further processed in the cell to yield the mature gastrins G34 and G17, before they are secreted into the bloodstream (Dickinson 1991). (The full citations for the references cited herein are provided in the Reference Section preceding the Claims). The mature forms of G34 and G17 are both amidated (NH₂) at their carboxy terminal end. It has been elucidated that there are multiple forms of G17 resulting from differential processing of the precursor molecule, each of which may have different biological activities (Dickinson 1995 and Ciccotosto et al. 1995).

The hormone gastrin is now a well recognized growth factor for human colorectal adenocarcinomas (see Watson et al. 1993 for a review). Elevated plasma levels of total gastrin occurs in patients with colorectal cancers, and in particular, increased amounts of the hormone precursor, progastrin, have been detected in many colorectal tumors using gastrin antisera (Ciccotosto et al. 1995).

Generally, in tumors such as those present in gastrin-dependent colon cancer, the cancer cells lose the ability to process prohormones to completion due to defects

in the regulatory pathways of hormone secretion. This leads to the production and secretion of different molecular forms of the hormone. Colon carcinoma cells do not efficiently process progastrin and thus, produce mostly incomplete or aberrant gastrins, which results in less conversion of precursor gastrin to the mature peptides (Dickinson 1993 and Rehfeld et al. 1993). The increased gastrin level in colorectal tumors is, in part, attributed to the aberrant expression of the gastrin gene in the colorectal tumor cells (Hoosein et al. 1990, Baldwin et al. 1992 and Finley et al. 1993). Gastrin-like peptides have been identified in such cells (Hoosein et al. 1988, Watson et al. 1991 and Finley et al. 1993), and were confirmed to be precursor gastrin species (Van-Solinge et al. 1993 and Nemeth et al. 1993).

Serum-associated G17 has the potential to stimulate the growth of colorectal tumors in an endocrine manner mediated by CCKB/gastrin receptors (Watson et al. 1993). Gastrin-17 appears to be particularly implicated in stimulating the growth of human colorectal adenocarcinomas due to a possible increased affinity for gastrin/cholecystokinin (CCK) B receptors on the tumor cells, over other gastrin hormone species (Rehfeld, J.F. 1972). The CCKB/gastrin receptors were found to be expressed in a high affinity form on 56.7% of human primary colorectal tumors (Upp et al. 1989). It has been postulated that a potential autocrine loop may also exist due to endogenous production of precursor gastrin peptides by such tumors (Van-Solinge et al. 1993 and Nemeth et al. 1993), as it has recently been shown that the precursor gastrin molecule, glycine-extended gastrin 17 (G17-Gly), stimulated the growth of a gastrointestinal tumor cell line. The trophic effects of G17-Gly on

tumors has been shown to be mediated by a receptor other than the CCKB/gastrin receptor and an autocrine growth loop, possibly involving gastrin precursors, has been postulated to be involved in the proliferation of gastrointestinal tumors (Seva et al. 1994).

Available treatments for tumors stimulated or induced by gastrin, and for tumors that produce gastrin consists primarily of surgical resection of the cancerous tissue. This approach is frequently unsuccessful; in many instances, the tumors cannot be located or are present in anatomic sites that are inoperable. In most instances, these tumors do not respond well to radiation or chemotherapy regimens, and new treatments are needed to supplement present procedures.

A number of high affinity CCKB/gastrin receptor antagonists have been described, such as L-365,260 (Bock et al. 1989) and CI-988 (Hughes et al. 1990), which have been shown to effectively neutralize the effects of exogenous gastrin on gastrointestinal tumor growth both *in vitro* and *in vivo* (Watson et al. and Romani et al. 1994). However, the antagonists lack specificity as they block the actions of all the potential ligands of the receptor, such as gastrin-34 (G34) and CCK. Moreover, the cellular receptors which recognize and bind the gastrin precursor, G17-Gly, do not bind all the inhibitors tested (Seva et al. 1994). Thus, if a distinct receptor is involved in the autocrine growth cascade, then the gastrin antagonists may be unable to block this mechanism of tumor growth promotion.

A therapeutic method of selectively immunologically neutralizing the biological activity of the gastrin hormone would provide an effective means of

controlling or preventing the pathologic changes resulting from excessive gastrin hormone production.

Co-assigned U.S. Patent Nos. 5,023,077 and 5,468,494 disclose immunogenic compositions useful for controlling G17 and G34 levels in a patient by generating anti-gastrin antibodies, and the use of such compositions for the treatment of gastric and duodenal ulcers and gastrin-induced cancers. The present invention concerns the use of the anti-G17 immunogenic compositions disclosed in the Patent Nos. 5,023,077 and 5,468,494 in the therapy of cancers whose growth is stimulated by precursor glycine-extended and amidated gastrin 17.

The method of cancer therapy described in this invention has several advantages over present treatment methods. The method is non-invasive, selectively reversible, does not damage normal tissue, does not require frequent repeated treatments, and does not cross the blood brain barrier.

SUMMARY OF THE INVENTION

The present invention provides immunological methods for the treatment of gastrin-dependent tumors which comprise the active or passive immunization of a patient with anti-G17 immunogen or antibodies against gastrin 17 hormone in order to control the patient's glycine-extended and amidated gastrin 17 levels. By inducing anti-gastrin 17 antibodies in a human patient, the hormone gastrin 17 and the prohormone progastrin G17-Gly are neutralized *in vivo*, so as to inhibit their physiological effects. In particular, the neutralization of G17 and the precursor G17-Gly prevents the binding of these peptides to their physiological receptors, thereby inhibiting the growth of the tumor cells.

The anti-G17 immunogens, comprise fragments of the N-terminal amino acids of G17 conjugated to an immunogenic carrier such as Diphtheria toxoid (DT), by a spacer peptide, and raise antibodies which bind both the amidated and glycine-extended forms of G17.

In one embodiment of the invention, the method of immunization against amidated or glycine-extended G17 comprises active immunization, wherein a patient is immunized with an immunogen of the invention. The immunogen stimulates the production of antibodies against amidated and glycine-extended G17 in the immunized patient, inducing sufficient antibody titers to neutralize and inhibit the physiological effects of amidated and glycine-extended G17 so as to limit the cancer-trophic hormone levels produced by the patient. The physiological neutralization of progastrin G17-Gly hormone by the anti-G17 antibodies produced in the patient

inhibits the growth of tumor cells dependent on progastrin G17-Gly as the growth stimulator or inducer. The treatment methods of the invention are particularly suited for the treatment of G17-Gly or amidated G17-responsive gastrointestinal cancers.

The immunogens of the invention comprise peptides composed of two functional regions: an immunomimic region and a spacer region. The function of the immunomimic region which immunologically crossreacts with G17 and G17-Gly, is to induce antibodies in the immunized animal that bind to the targeted G17 hormone, i.e. amidated and glycine extended G17, thereby inhibiting G17 function and arresting or slowing the growth of the G17-dependent tumor cell. The present immunogens induce a biologically effective immune response following administration of the immunogen in all immunized animals tested. The immunomimic peptide-spacer of this invention can be coupled to immunological carriers over a wide range of peptide to carrier substitution ratios and yield effective immunogens.

In another embodiment of the invention, the method of treatment comprises passive immunization, in which antibodies against G17 are administered to the patient in a sufficient concentration to reduce the levels of circulating unbound G17 and G17-Gly. The reduced levels of free G17 and progastrin in the circulating blood of a patient as a result of anti-G17 antibody administration, results in an inhibition of the growth of the tumor cells, thereby stopping or reducing the growth and size of the tumors. In a preferred embodiment of this aspect of the invention,

the anti-G17 antibodies for human therapy may be chimeric, humanized, or human monoclonal antibodies which may be produced by methods well known in the art.

BRIEF DESCRIPTION OF THE DRAWINGS

Figure 1 is a diagrammatical representation of glycine-extended G17, carboxy-amidated G17 and an anti-G17 immunogen containing an amino terminal portion of G17.

Figure 2 is a graphic representation of the displacement of [125 I]G17 from rabbit anti-human G17(1-9):DT (N-terminal specific) antiserum by G17, glycine-extended G17 and G34.

Figure 3 is a graphic representation of the displacement of [125 I]G17 from rabbit anti-human G17 (C-terminal specific) antiserum by G17, glycine-extended G17 and G34.

Figure 4 depicts a bar graph on the effect of immunizations with the immunogens of the invention on the median cross-sectional areas of DHDK12 tumors (inter-quartile ranges for each median are present at the top of the respective columns).

Figure 5 depicts a bar graph on the effect of immunizations with the immunogens of the invention on the final median weights of DHDK12 tumors (inter-quartile ranges for each median are present at the top of the respective columns).

Figure 6 depicts the anti-rat G17 antibody levels of individual G17(1-9)- and DT-immunized rats (measured at a 1:100 dilution of sera).

- 1 At tumor challenge (rat G17(1-9) treatment, 5 immunizations)
- 2 At therapy termination (rat G17(1-9) treatment, 7 immunizations)
- 3 At tumor challenge (DT treatment, 5 immunizations)
- 4 At therapy termination (DT treatment, 7 immunizations)
- 5 Positive control (rat anti-rat G17:DT antiserum)
- 6 Negative control (normal rat serum)

Antibody levels were measured by an ELISA capture assay in which anti-rat G17:DT antibodies bound to rat G17-BSA coated on 96 well microtiter plates. Antibody binding was detected using an alkaline phosphatase based method with pNPP as substrate.

DETAILED DESCRIPTION OF THE INVENTION

The methods of the invention are directed to administering to a patient an anti-G17 immunogen which induces antibodies in the immunized patient which bind and neutralize amidated-G17 and glycine-extended G17 (see Figure 1).

Surprisingly, the immunogens and immunogenic compositions against G17 disclosed in co-assigned U.S. Patent Nos. 5,023,077 and 5,468,494, also produce antibodies in immunized animals which react with and neutralize amidated gastrin 17 and glycine-extended gastrin 17. Advantageously, therefore, these immunogens may be used in methods of treating cancer disease states which are trophic due to these precursor hormones.

U.S. Patent Nos. 5,023,077 and 5,468,494, the disclosures of which are hereby incorporated by reference in their entirety, disclose compositions containing anti-gastrin 17 immunogens and methods of using these compositions for the treatment of gastric and duodenal ulcers and gastrin induced cancers. The present invention concerns the use of the same anti-G17 immunogens to treat disease states such as gastrointestinal cancers which are affected by the prohormone G17-Gly.

In the present invention, a serum sample from the patient having a gastrointestinal cancer can be assayed to determine the level of G17-Gly in the patient's blood. An effective dosage ranging from 0.001 to 2mg of the immunogenic composition is administered to the patient for the treatment of the gastrointestinal cancer. The effective dosage of the immunogenic composition should be capable of eliciting an immune response in a patient of effective levels of antibody titer against both human gastrin 17 and the G17-Gly within 1-3 months after immunization. Following the immunization of a patient, the antibody titer levels against amidated or glycine-extended G17 are monitored from a sample of blood taken from the patient, and booster immunizations should be given as required

to maintain an effective antibody titer which will neutralize G17-Gly and amidated G17. The effective antibody titer which will neutralize G17-Gly and amidated G17 is defined as the minimum antigen binding capacity of 5 picomoles of antigen-bound in one milliliter of the patient's serum, as measured by standard immunological assays. In addition, serum G17-Gly can be monitored to assess the effectiveness of immunization against G17. Effective treatment of gastrointestinal cancers such as colorectal adenocarcinomas, according to this method should result in inhibition of tumor growth and a decrease in size of the tumor.

The antibody titers raised by the anti-G17 immunogens are in excess of those required to neutralize serum G17 resulting in high serum levels of uncomplexed antibodies which are free to bind to G17-Gly. Thus, the 'free' serum-associated antibodies would be available to neutralize cell-associated G17 peptides in well-vascularized areas of the tumors.

Antibodies raised by the anti-G17 immunogens of the present invention may have significant anti-trophic effects against gastrointestinal cancer, such as a colon tumor by two potential mechanisms: (i) neutralization of serum G17, and (ii) neutralization of cell-associated precursor gastrin molecules.

The following examples demonstrate the effect of active immunization with rat G17 immunogen on the *in vivo* growth of the rat colon cancer line, DHDK12. DHDK12 is a rat colonic tumor cell line of epithelial morphology (Martin et al. 1983). The immunogen tested is composed of the N-terminal 9 amino acids of G17 linked to DT by a spacer peptide, and can be made specific for either human or rat

G17. Antiserum raised by anti-G17 immunization is denoted as anti-G17(1-9):DT and contains a spacer peptide.

Example 1

These experiments demonstrate that the immunogen induces antisera that bind to amidated G17 and glycine-extended G17, but not to G34.

Gastrin-specificity of antiserum raised by anti-G17 immunization of rabbits

Antisera were absorbed onto a solid phase at a concentration of 100 μ g/ml and displacement was determined in a competitive assay with a fixed concentration of radiolabelled G17 (1000 pg/ml) and increasing concentrations of unlabelled ligands (1-25,000 pg/ml).

Figures 2 and 3 show the displacement of [125 I]G17 from rabbit anti-human G17 antiserum by G17, G17-Gly and G34. The antiserum used in the test depicted in Figure 2 was obtained from animals immunized with G17(1-9):DT and was specific for the N-terminal end of G17; the antiserum for Figure 3 was specific for the C-terminal end of G17. G17 displaced radiolabelled G17 from both antisera preparations with a 50% inhibitory concentration (IC_{50}) of 3500 pg/ml for the rabbit anti-human G17 (1-9):DT (N-terminal) and 800 pg/ml for the rabbit anti-G17 (C-terminal). Glycine-extended G17 did not displace radiolabelled G17 from the C-terminal specific antiserum, but did from the N-terminal specific antiserum (IC_{25} 12,000 pg/ml), demonstrating that the glycine-extended G17 binds to N-terminal specific antiserum, but not to C-terminal specific antiserum. G34 displaced

radiolabelled G17 from the C-terminal (IC_{25} 500 pg/ml), but not the N-terminal specific antiserum, demonstrating the specificity of the G17(1-9):DT antiserum for G17 and glycine-extended G17 and not to G34.

Example 2

These experiments show that the DHDK12 rat colonic cells produce glycine-extended gastrin 17 and that anti-G17 antiserum reduces the levels of precursor gastrin produced by the cells.

Radioimmune assay of precursor gastrin levels

DHDK12 cells were grown to sub-confluence in RPMI 1640 culture medium (Gibco, Irvine, Scotland, UK) supplemented with 2mM glutamine (Sigma, Poole, Dorset, UK) and 10% heat-inactivated foetal calf serum (FCS, Sigma). The cells were incubated in humidified conditions at 37°C with 5% CO_2 . Cells were harvested with 0.025% EDTA (15 minutes at 37°C), washed by centrifugation and 2×10^6 cells seeded into flasks containing serum-free medium (RPMI 1640 in a 1:1 ratio with Hams F12 (Gibco) with 0.5% bovine serum albumen [BSA]). Cells were harvested with 0.025% EDTA, washed, re-suspended in 1ml of sterile distilled water and heated in a boiling water bath. The levels of glycine-extended gastrin were measured by radioimmunoassay (RIA) using antibodies 109-21 and L-2 as described (Nemeth et al. 1993).

Levels of Gastrin precursors associated with DHDK12 cells

DHDK12 cells were shown to contain glycine-extended gastrin, but not amidated G17, in two separate experiments as shown in Table 1.

Table 1 Precursor gastrin levels associated with DHDK12 cells

	Glycine-extended G17 conc. (fmol/10 ⁷ cells)	Amidated G17 conc (fmol/10 ⁷ cells)
Experiment 1 (1.0 x 10 ⁷ cells/ml)	31.2	ND ¹
Experiment 2 (1.27 x 10 ⁷ cells/ml)	80.0	ND ¹

Tumor cell extracts were prepared by heating cells in 1ml of sterile water. Cell extracts were recovered by centrifugation and progastrin, glycine-extended gastrin and amidated G17 levels were measured using antibodies 109-21 and L-2 respectively, as previously described (Nemeth et al. 1993).

¹ND - Not detected

Effect of rabbit anti-ratG17:DT treatment on the precursor gastrin levels of DHDK12 cells

Semi-confluent DHDK12 cell monolayers were prepared as described previously in serum-free medium and harvested with 0.025% EDTA. Affinity purified rabbit anti-ratG17:DT and rabbit anti-DT (negative control) were then added to the flasks at equivalent protein concentrations to give an antigen binding capacity for the former of

3 ng/ml. The cells were incubated for 4 days after which cell extracts were prepared and assessed for precursor gastrin levels by the RIA described above.

The effect of *in vitro* treatment with affinity purified rabbit anti-ratG17 (1-9):DT and rabbit anti-DT antisera on the precursor gastrin levels associated with DHDK12 cells in serum-free medium is shown in Table 2.

Table 2 Precursor gastrin levels of DHDK12 cells after *in vitro* treatment with rabbit anti-G17(1-9):DT antiserum

Treatment	Glycine-extended G17 conc. (fmol/10 ⁶ cells)	Amidated G17 conc (fmol/10 ⁶ cells)
Rabbit anti-G17(1-9):DT antiserum	ND ¹	ND ¹
Rabbit anti-DT antiserum	67.0	ND ¹

DHDK12 cells were grown in serum-free medium (RPMI 1640 in a 1:1 ratio with Hams F12 with 0.5% bovine serum albumen). Affinity purified rabbit anti-rat G17(1-9):DT and rabbit anti-DT were then added to the flask at a protein concentration of 3 ng/ml and incubated for 4 days. Cell extracts were recovered by centrifugation and progastrin, glycine-extended gastrin and amidated G17 levels were measured using antibodies 109-21 and L-2 respectively, as previously described (Nemeth et al. 1993).

¹ND Not detected

As can be seen in Table 2, rabbit anti-ratG17:DT antiserum reduced the levels of glycine-extended G17 from 67 pg/ml to undetectable.

DHDK12 cells were also shown to express cell-associated glycine-extended G17 but not amidated gastrin. *In vitro* treatment of DHDK12 cells with rabbit anti-ratG17 (1-9):DT reduced the levels of cell-associated precursor gastrin when compared to cells treated with rabbit anti-DT control antiserum. Thus, antibodies produced by anti-G17 immunization may interrupt an autocrine growth loop involving such peptides as a consequence of down-regulation of gastrin translation.

Example 3

The following experiments demonstrate that immunization of rats with the Rat G-17 (1-9) DT immunogen markedly inhibits the growth of DHDK12 tumors *in vivo*.

Experimental animals

Male BDIX rats (The Animal Unit, University of Liverpool, UK) of age 6-10 weeks weighing 340-430g were housed in pairs and maintained in a cycle of 12 hours light and 12 hours dark at 25°C with 50% humidity. The rats were allowed to acclimatize for at least 7 days before use.

Immunization procedure

Rat G17(1-9) coupled to DT or the DT component alone were dissolved in sterile saline (0.9%), pH 7.3 at 1mg/ml. The adjuvant nor-muramyl dipeptide (nor-MDP, Peninsula Labs., CA) was added to the conjugate to give a final concentration of 500 µg/ml. The aqueous solution was mixed with oil (Montanide ISA 703 AMS Seppic, Inc., Paris, France) in a 1:1 ratio (vol:vol) and placed in a glass syringe which was attached to a second syringe with a three-way stopcock as

connector and the mixture forced back and forth through the syringes 100 times (the stopcock produced a right angle shear to assist emulsification).

Control animals received an identical emulsion containing the DT peptide only, and all experimental groups were equalized with respect to weight. A 200 μ l volume of the emulsion was injected subcutaneously (s.c.) in the right hand flank of the experimental animal. The animals were immunized at 21 day intervals and the tumor implanted after 5 immunizations.

Initiation of tumor growth

DHDK12 cells were suspended in sterile 0.9% saline at a concentration of 2.5×10^7 /ml. Rats were anaesthetized by a 1ml injection of Hypnorm (Fentanyl citrate 0.315 ng/ml and Fluanisone 10 mg/ml, Janssen, Belgium), Hypnovel (Midazolan 5 ng/ml, Roche, Switzerland) and sterile distilled water in a 1:1:5 ratio. Following a s.c. incision on the right flank, a 200 μ l volume of the cell suspension was injected into the muscle layer of the abdominal wall and the surgical incision closed with a wound clip. Each experimental group consisted of between 16-18 rats.

Effect of rat Anti-G₁₇ immunization on the *in vivo* growth of DHDK12 tumors

Figures 4 and 5 show the effect of immunization with rat G17(1-9)-DT immunogen (5 immunizations prior to injection of cells) on the final cross-sectional areas and weights, respectively, of DHDK12 tumors. The tumors had significantly reduced cross-sectional areas in rats immunized with anti-G17 immunogen. Figure 4 illustrates data which show that the median cross-sectional areas of tumors from anti-G17 treated rats were reduced by 70.2% when compared to tumors from the DT

controls, $p=0.005$, Mann Whitney. DHDK12 tumors also had significantly reduced tumor weights in rats immunized with anti-G17 immunogen. Figure 5 shows that DHDK12 tumor weights were reduced by 56.5% when compared to tumors from the DT controls, $p=0.0078$. The mean animal weight in the anti-G17 treated rats rose from 399 g to 452 g (13% increase) over the duration of the experiment and in the DT- treated animals from 392 g to 447 g (13.8% increase) indicating that the growth rate of the animals was not affected by administration of the G17(1-9)-DT immunogen.

Example 4

The experiments show the levels of anti-rat G17 antibodies induced in immunized rats that were implanted with DHDK12 tumors.

Anti-rat G17 antibody levels of rat G17(1-9): DT-immunized rats

To determine the antibody response to the emulsified rat G-17(1-9)DT immunogen, rats were tail-bled at various time points and an ELISA technique was used to determine the anti-rat G17:DT antibody titers.

A rat G17-BSA conjugate was prepared at a concentration of 2 $\mu\text{g/ml}$ in Glycine buffer (0.1M, pH 9.5) and 25 μl was plated per well into 96-well Immulon U plates (Dynatech Labs., Sussex, UK) and incubated overnight at 4°C. The unabsorbed conjugate was then flicked out and the wells washed in buffer which consisted of 0.9% saline, pH 7.3 containing 0.5% Tween-20 (Sigma) and 0.02% NaN_3 (Sigma). This buffer was used for both washing and reagent dilutions. The test sera (from animals immunized with the rat gastrin immunogen) were used at a starting

dilution of 1:100 and at 10 fold dilutions thereafter. The positive control was rat anti-rat G17 antiserum from previously immunized animals and the negative controls were normal rat serum and sera from rats immunized with DT. These were used at the same dilutions as described for the test sera. The test and control sera were added to the wells in 25 μ l volumes either in the absence or presence of 25 μ l/well rat G17-BSA at 100 μ g/ml (control wells received 25 μ l assay buffer). The plates were then incubated for 60 minutes at room temperature. The plates were washed with saline buffer, then goat anti-rat Ig (H+L)-biotin (Zymed, San Francisco, CA) was added to the wells at a 1:500 dilution, 50 μ l/well, and incubated for 60 minutes in the dark at room temperature. The plates were washed with saline buffer and avidin alkaline phosphatase (Zymed) was added to wells at a 1:100 dilution, 50 μ l/well and incubated for 60 minutes in the dark at room temperature. After washing with saline buffer, *p*-nitro-phenylphosphate (pNPP) substrate (Sigma) in substrate buffer was added to the wells at 50 μ l/well and after 5 minutes developing time the absorbance was read at 405nm. The difference in absorbance between untreated sera and sera co-incubated with rat G17-BSA was calculated as the specific absorbance.

The free anti-rat G17(1-9):DT antibody levels (those in excess of the antibodies required to bind serum-associated G17) were measured and are expressed as the specific absorbance obtained at a 1:100 dilution of serum (Figure 6). After 5 immunizations, at the time of tumor cell injection, the mean antibody level was 0.243 absorbance units (Group 1 in Figure 6). The mean antibody level had increased, by the termination of the study, following 2 further immunizations, to 0.66 absorbance

units (Group 2 in Figure 6) and were in the range of the positive control (Group 3 in Figure 6). Antibody levels from animals immunized with DT had a mean absorbance of 0.1 units (Groups 4 and 5 in Figure 6) and the negative control (normal rat serum) showed no absorbance (Group 6 in Figure 6). There was no apparent correlation between tumor weight and antibody levels as measured by a Linear Regression Analysis, ($p=0.14$).

Example 5

The following experiments show that immunization against G17 reduced serum G17 levels and that these reduced levels correlated with reduced tumor growth.

G17 levels in the immunized rats as determined by an inhibition RIA

Rabbit anti-G17 antiserum (C-terminal-specific, Dakopatts, Bucks., UK) was coated onto 96-well microtitre plates at a protein concentration of 10 ng/well in PBS. A standard curve was constructed by incubating [125 I]G17 at a fixed concentration of 10,000 CPM/well with increasing concentrations of G17.

The unknown samples containing free gastrin, bound G17, free and bound anti-G17 antibodies were prepared in 250 μ l aliquots. A 125 μ l aliquot of newborn calf serum (Sigma) and 312.5 μ l of 25% polyethylene glycol (Sigma) were added to each sera sample. These were vortexed and spun at 1500 rpm for 30 minutes. The supernatant was removed and boiled (to ensure no free antibodies remained) and was classified as the free gastrin sample.

The pellet was washed 5 times in 0.002 M veronal buffer (pH 8.4) containing 0.5% bovine serum albumen and solubilized by boiling in 250 μ l of water. This was classified as containing bound gastrin. Triplicate aliquots of each of the samples were added to the labelled G17 and the level of inhibition was determined. Gastrin levels in the rat sera were then calculated from the standard curve.

The free serum gastrin level (as measured with an antiserum directed against the carboxy terminus of G17) of the DT-immunized rats was found to be 114.0 pg/ml (standard deviation of 31) compared to 68.5 pg/ml (standard deviation of 20) in the rat G17(1-9): DT-immunized group. This corresponds to a 40% reduction in total gastrin. Total serum gastrin levels were correlated with final tumor weight and the correlation coefficient was found to be statistically significant, ($p=0.011$, Linear Regression Analysis. The levels of serum gastrin bound to antibodies was found to be zero in the DT-immunized rats and ranged from 30.1 to 253.7 pg/ml in the rat G17(1-9): DT-immunized rats (median of 53.3 pg/ml).

DHDK12 rat colon tumor cells growing *in vivo*, by virtue of their CCKB/gastrin receptors, have responded to serum G17. In these experiments, excess anti-G17 antibodies (i.e. those not bound to serum G17) were measured during the tumor challenge. The total serum gastrin levels were shown to be reduced by 40% and a significant positive correlation was shown between tumor weight and serum gastrin levels at the termination of the therapy. In addition, antibody-bound gastrin was also detected in the rat G17(1-9): DT immunized, but not in the DT-immunized,

rats. Thus, neutralization of serum-associated gastrin contributed to reduced tumor growth.

Example 6

The experiments show that immunization against G17 affects the histological appearance of DHDK12 tumors.

Histological evaluation of the rat tumors

At termination of therapy, the DHDK12 tumors were fixed in 10% formal calcium and embedded in paraffin. 5 μ m sections were cut on a cryostat, stained with Haematoxylin and Eosin and the pathological parameters of the tumors assessed independently by a Pathologist. Image analysis was performed on the tumor sections using a Seescan Image Analyzer in a blind manner to assess the area of viable tumor tissue.

Gastrin receptors (GR) were detected using a rabbit anti-CCKB/gastrin receptor polyclonal antiserum. Sections were incubated with a 1:500 dilution overnight at 4°C. Binding was detected using the avidin-biotin technique with immunoperoxidase as the enzyme tracer and diaminobenzidine as the substrate.

Histological evaluation revealed that the tumors from rat G17(1-9):DT-immunized rats had a smaller rim of viable tumor tissue around the leading edge of the tumor and a greater degree of central necrosis when compared to tumors from rats immunized with DT. This was quantified by image analysis and the mean percentage of viable cell area in tumors from rat G17(1-9):DT-treated rats was 40.3%

(standard deviation of 9.1) compared to 58.6% (standard deviation of 10.4) for the DT-immunized rats ($p=0.003$, Student's *t* test).

Higher magnification microscopy showed that the tumor cells in the DT-immunized rats grew in a regular trabecular manner, whereas the tumor cells from G17(1-9):DT-immunized rats had a disrupted pattern of growth. There was also more connective tissue in the tumors from G17(1-9):DT-treated rats when compared to tumors from DT-treated rats (connective tissue:tumor ratio being 75:25 and 50:50, respectively). Areas of focal necrosis were present within the viable tumor tissue in the G17(1-9):DT treated group and also an increased inflammatory infiltrate which appeared to be composed mostly of lymphocytes. The tumors from rats in both treatment groups were stained with anti-GR antiserum and it was shown that the viable cells remaining in both the DT and the G17(1-9):DT treated groups had retained their GR positivity.

Immunization with the G17:DT immunogen reduces the *in vivo* growth of DHDK12 rat colon tumors as shown by both cross-sectional area and weight measurements. Extrapolation of quantitative assessment of viable tumor tissue by image analysis indicated that the weight of viable tumor tissue may have been reduced by as much as 68%.

One further finding was the focal areas of necrosis within the tumor tissue in anti-G17 treated rats and the presence of an inflammatory infiltrate in certain areas of the tumor which was mainly composed of lymphocytes. One possible explanation of such findings is that an antibody-dependent cellular cytotoxic response

was instigated by the anti-G17 immunogen. The mechanism of such a response as applied to immunization against G17 is unknown.

Anti-G17 immunization resulted in the potential neutralization of two trophic forms of gastrin, G17 and glycine-extended G17, and thus may induce cytostasis within the tumors. The histological observations provide evidence for the theory that tumors from anti-G17 immunogen treated rats have a slower growth rate than tumors from control rats as the growth pattern, the degree of fibrosis and the area of the viable tumor tissue was significantly reduced in the former rats. Interestingly, the viable tumor cells remaining were shown to maintain their expression of GR. This indicates that in this tumor model, the gastrin hormone-sensitive phenotype may have been expressed by all the cell clones and there was no outgrowth of gastrin hormone-insensitive clones leading to escape from anti-G17 immunogenic inhibition.

Example 7

Immunocytochemical evaluation of the CCKB/gastrin receptor expression of DHDK12 cells

DHDK12 cells were suspended at a concentration of 1×10^6 /ml and 200 μ l volumes were cytopun onto microscope slides (1200 rpm, 5 minutes). The cells were fixed with methanol at -20°C (5 minutes) and permeabilized by treatment with graded alcohols. The cells were incubated with the rabbit anti-CCKB/gastrin receptor antiserum and stained as previously described.

CCKB/gastrin receptor expression of DHDK12 cells was evaluated with antiserum raised against peptide sequences derived from the human CCKB/gastrin receptor. DHDK12 cells showed a strong and specific membrane-associated immunoreactivity indicative of a high level of gastrin receptor expression. Cells treated with a control rabbit antiserum showed no specific immunoreactivity.

References

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